

FARM SAFETY

By Nellie Brown

What every person who works around manure should know. This is a matter of life or death.

Work safely around manure gases

Manure gases can be deadly, especially in confined spaces, and the risks must be taken seriously.

As bacteria grow in the confined space, using manure as a food source, they generate toxic gases and consume oxygen in the space, producing a dangerous or deadly atmosphere. Wherever there is manure, or even moisture or standing water in a confined space, bacterial growth will deplete the oxygen levels and produce gases with serious hazards of fire/explosion and toxicity.

A 2007 *Journal of Agromedicine* review of fatalities and injuries associated with manure storage and handling from 1975 to 2004 found that:

- Over half involved dairy operations; 21% involved persons younger than 16.
- 34% of deaths were the persons performing repair or maintenance on manure handling equipment.
- 22% of deaths were would-be rescuers performing rescue of another person.
- Most frequently-identified cause: asphyxiation, with elevated levels of sulfide in the blood noted in some cases.
- Peak period of incidents was during the hottest part of summer.

Why do deaths occur?

Many times the hazard isn't recognized or the danger is underestimated, the person trusts their senses or is complacent, or, and very often, they are trying to save someone else.

In a manure pit, or similar spaces, the gases of particular interest are methane, carbon dioxide and hydrogen sulfide. Typical percent compositions for anaerobic digester gas derived from manure are:

- Methane 50 to 60%

Asphyxiation from methane alone can occur at 87% due to oxygen deficiency. Lower explosive limit (LEL) is 5%. Upper explosive limit (UEL) is 15%.

- Carbon dioxide 38 to 48%

At concentrations of 11% or above unconsciousness occurs in a minute. At 25 to 35% convulsions occur. Carbon dioxide is considered immediately

dangerous to life and health at 50,000 ppm or 5%.

- Hydrogen sulfide 580 ppm

Hydrogen sulfide is immediately dangerous to life and health at 100 ppm. At about 500 ppm pulmonary edema (chemical pneumonia) can cause an imminent threat to life and strong nervous system stimulation, which can cause breathing to stop. At levels of 100 ppm or higher, hydrogen sulfide has no odor, so there is no warning of its presence.

As these gases are generated, they push out the air originally in the space, leading to asphyxiation by oxygen deficiency, toxicity or explosive conditions. An atmosphere is considered oxygen-deficient if the oxygen concentration is less than 19.5%. Compare this to the typical oxygen content of air at 21%.

Confined space

Confined space is one of the most important hazards that needs to be addressed in manure handling and biogas generation. It includes pits, tanks, vessels and digesters. While the Occupational Safety and Health Administration (OSHA) does have a regulation on confined space entry (USDOL. OSHA. 29 CFR 1910.146 Permit-Required Confined Spaces), it does not apply to agriculture. However, OSHA could still cite an employer for a confined space problem under the general duty clause of the OSHA Act because it is a well-known problem capable of causing death or serious physical harm.

OSHA's definition for a confined space is that it has limited openings for entry and exit, has unfavorable natural ventilation that can contain or produce dangerous air contaminants, and is not intended for continuous employee occupancy. There is no real size criterion, so long as the space is large enough for a person to enter and do work.

In addition to atmospheric hazards, a confined space may also have:

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- mechanical hazards such as agitators, mixers, or pumps, needing lockout/tagout, line-breaking, or other procedures
- engulfment, such as drowning
- entrapment, such as sloping bottoms of pits or tanks which can cause someone to become wedged in an outlet

A confined space may simultaneously have multiple hazards.

Every farm should have safety procedures in place and on file. These should include the hazards associated with agriculture manure storage structures and equipment and confined spaces that need appropriate warnings and entry procedures. OSHA confined space entry procedures should be incorporated into work practices, even though the regulation does not specifically include farms.

Recommendations by the National Institute of Occupational Safety and Health, which is part of the US Centers for Disease Control, are that manure pits on farms should be treated like any other type of confined space. As such:

- all manure pits should be ventilated,
- the atmosphere within the pit should be tested before entry,
- a standby person should be in constant contact and ready to lift the worker to safety with mechanical lifting equipment, such as a winch, hoist, or pulley, and
- anyone entering a manure pit should wear a safety belt or harness with a lifeline tied to the mechanical lifting device.

Hierarchy of Controls

To reduce hazards or risks, stay as high up on the Hierarchy of Controls as possible. The hierarchy is a structured approach to hazard reduction, endeavoring to use the most effective methods as the first choice. Some potential hazard reduction or elimination methods in this hierarchy are:

1. Source elimination is the most powerful method. This includes hazard substitution such as using a safer chemical for a cleaning job. Or, process change, such as designing out the need for confined space entry for a maintenance task on a manure pit pump.
2. If this is not possible, consider engineering controls such as ventilation, or attaching a pump or agitator to a winch so that it can be brought out of the confined space whenever it needs maintenance.
3. If these do not work or are not suf-

Fatalities

Injury and fatality have occurred on farms because of confined space work, especially after entry into manure pits and wells. Often people don't realize that the hazardous conditions may not be seen or smelled or that equipment needs to be inactivated so it can't be started up while someone is in the space.

The younger son of a dairy farmer entered a manure pit to replace a shear pin on an agitator shaft. While attempting to climb out of the pit he was overcome and fell to the bottom. The dairy farmer's grandson then entered the pit to attempt a rescue. He too was overcome and collapsed. The nephew, an older son, and the dairy farmer then entered the pit one at a time, attempting to rescue those already overcome. Each was overcome and collapsed in turn. A carpet installer working at the farm house then entered the pit to attempt a rescue. He too was overcome but was rescued by his assistant and subsequently recovered. Finally, the owner of a local farm implement business arrived on the scene with two of his workers and, using a rope, extricated the five victims from the pit. When the local emergency rescue squad arrived on the scene approximately 20 minutes after the incident they immediately began cardiopulmonary resuscitation. The nephew was pronounced dead at the scene. The remaining four victims were transported to the local hospital. The farmer and his younger son were pronounced dead on arrival, and the older son died an hour after reaching the emergency room. The grandson was transferred to a major trauma center by helicopter but he died approximately six hours after his removal from the pit.

Two dairymen prepared to repair a gate valve in an open manure holding tank. After emptying the tank, which was 10 to 12 feet deep, the first man climbed down and plugged the 12-inch transfer pipe with rags and wood to hold back manure from the main storage. Backpressure inside the pipe blew out the rags, and manure instantly began filling the holding tank, along with a cloud of gas. The man in the tank immediately tried to climb out, but collapsed down into the liquid manure. The other man, standing above on the floor at the opening of the tank, immediately bent down to try to grab hold of the victim and pull him out. He was also instantly overcome by the gas and fell down into the holding tank. Both of the men were now unconscious in the rapidly filling tank. A third person, standing nearby, also started to lose consciousness. A fourth person, who had witnessed the accident from outside the room, ran in, pulled him to safety and called the rescue squad. The first two men died; the third person survived but was severely disabled.

A 31-year-old male dairy farmer and his 33-year-old brother died after entering a 25-foot-square, 4-1/2-foot-deep manure pit inside a building on their farm. A pump intake pipe in the pit had clogged and the farmer descended into the pit to clear the obstruction. While in the pit he was overcome and collapsed. The victim's brother was standing at the entrance of the pit and apparently saw the victim collapse. He entered the pit an attempt to rescue him. The brother was overcome and collapsed inside the pit. Four hours later another family member discovered the two victims inside the pit and called the local fire department to rescue them. The victims were pronounced dead at the scene by the coroner.

A father and son were pumping out an anaerobic digester so that inspection and maintenance could be performed. After pumping for several hours the thick bottom sludge became very difficult to pump and a cold water line was placed in the digester through a port in the cover to dilute the sludge. This was successful and the pumping was continued. After a while the two workers thought that the digester was about empty, so they lowered a trouble light on an extension cord through the port in the cover. The result was an explosion that killed the two men. Upon investigation, it was hypothesized that the hot bulb contacted the cold water and cracked, exposing the bulb element to the residual methane in the digester, causing the explosion. □

ficient, then consider administrative controls such as work practices and procedures or work rules and policies.

4. If these do not work or are not sufficient, then consider personal protective equipment such as a respirator, clothing, gloves, ear plugs or muffs, or a face shield.

If designing a manure pit, manure storage system or anaerobic digester, consider maintenance tasks and not just operations tasks. Plan ways to avoid the necessity of confined space entry to accomplish the task. The safest systems are designed so that there is never any need for confined space entry to perform maintenance.

Testing the air

While recommendations emphasize air testing, also consult the industry standard: ANSI/ASABE S607 Oct2010 Ventilating Manure Storages to Reduce Entry Risk, available at www.asabe.org.

Before entry into a confined space, test the air with a calibrated direct-reading instrument for:

- oxygen content (should be 19.5 – 23.5%)
- flammable gases and vapors (should be <10% LEL)
- potential toxic air contaminants (should be less than OSHA PEL: for hydrogen sulfide <20 ppm)

These items must be tested in that order. Test from the top to the bottom of the space so that gases that are lighter-than-air or heavier-than-air are found if present.

If the atmosphere is unacceptable, use forced air ventilation, such as a blower and hose, to bring the atmosphere to acceptable levels. Periodically re-test as necessary to ensure that continuous forced air ventilation prevents the accumulation of a hazardous atmosphere. If a hazardous atmosphere is detected while anyone is in the space each person should leave the space immediately. Evaluate the space to determine how the hazardous atmosphere developed.

Some considerations for air testing:

- Use the test instrument in accordance with the manufacturer's specifications.
- When testing stratified atmospheres, test approximately four feet in the direction of travel and to each side. Slow the entrant's travel to accommodate the instrument's sampling speed and detector response.

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Signage

All hazardous areas should have appropriate signage. Without agitators, mixers, or other such equipment in the space, the sign might read:



With agitators, mixers, or other such equipment in the space, the sign might read:



Any warning signage should be in multiple languages if needed.

changes or any hazards that cannot be eliminated.

6) General Communications - Inform all non-essential personnel to stay out of and away from the bunker and post warning signs where practical.

Though written records relating to bunker silo safety are not legally required by OSHA, farms will be in the best position by keeping files that include: the instructor(s) and dates of training, topics covered, materials used for training/or sources of training, and signatures by all who attended.

Additionally, farms should consider having complete, accurate, written procedures for bunker silos, including filling, covering, and unloading and be sure that employees have been trained on following them.

Farms with silage bags, drive-over piles and tower silos will

have specific safety related items under an OSHA inspection, many of which are included in the list above.

Based on the discussions with OSHA, it is clear that the dairy industry will need to make safety related changes in bunk design and standard operating procedures (management) in the coming years. While the nature of many of these changes is uncertain at this time, it would be helpful for each farm to give consideration to how their bunker systems can be made safer.

A technical work group has formed in NYS to evaluate current options and to develop other viable solutions. We will distribute and post new information as it becomes available on PRO-DAIRY, Northeast Dairy Producers Association (NEDPA), New York Center for Agricultural Medicine and Health (NYCAMH) and other Web sites. □

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■ A standby person should be in constant contact and ready to lift the worker to safety with mechanical lifting equipment (winch, hoist, or pulley), and

■ Anyone entering a manure pit should wear a safety belt or harness with a lifeline tied to the mechanical lifting device.

Entering a confined space

If confined space entry is necessary, this may involve draining of the tank(s) or digester, and lockout of pumps or agitators. Feed to the raw manure tank should be discontinued. Perhaps manure could be diverted to storage in the interim, if necessary. Overall, if entry does become necessary, written procedures should be developed for confined space entry with the appropriate lockouts and isolation procedures.

Mechanical ventilation is the preferred method to achieve an acceptable atmosphere. However, entry can also be accomplished using a supplied-air respirator. The worker wearing the respirator will need to be clean-shaven where the respirator seal meets the face. Even one day's growth of beard may allow leakage of the respirator, which is comparable to not wearing a respirator at all.

Maintaining testing equipment

Working safely around manure requires maintaining proper equipment for testing. The most important elements of gas detector maintenance are function ("bump") testing and calibration. Bump testing involves using a prepared gas mixture of known composition to test that the sensors are working. All gas sensors lose sensitivity over

time, and even more rapidly in the field, due to temperature, humidity, dust, dirt and rough handling. Calibration adjusts the readings to account for these changes and to monitor the conditions of the sensors so that they can be replaced as needed.

Sensor type	Typical life span
Oxygen sensors	1.5 – 2.0 years
Catalytic bead combustible gas sensors	3 – 5 years
Electrochemical toxic gas sensors	1 – 4 years
Infrared gas sensors	5 – 10 years
Photoionization gas sensors	2 – 4 years

Resources:

■ USDOL. OSHA. 29 CFR 1910.146 -- PERMIT-REQUIRED CONFINED SPACES. <http://www.osha.gov>

■ USDHHS/CDC/NIOSH. Preventing Deaths of Farm Workers in Manure Pits

■ <http://www.cdc.gov/niosh/90-103.html>

■ USDHHS/CDC/NIOSH. NIOSH Warns: Manure Pits Continue to Claim Lives. <http://www.cdc.gov/niosh/updates/93-114.html>

■ USDHHS/CDC/NIOSH. Hydrogen Sulfide in Manure Handling Systems: Health & Safety Issues. Fact Sheet S-1. http://www.manuremanagement.cornell.edu/Pages/Resources/Resources-Fact_Sheets.htm

■ Brown, N. J. 2007. Conducting a Safety Walk-Through on a Farm: Hazards of the Manure Handling System, Anaerobic Digester, and Biogas Handling System

A SELF-ASSESSMENT GUIDELINE FOR FARMERS <http://www.manuremanagement.cornell.edu/Pages/Topics/Safety.html>

■ ANSI/ASABE S607 Oct2010 Ventilating Manure Storages to Reduce Entry Risk is now available at www.asabe.org □